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DESCRIPTION

VIBRATION PIEZOELECTRIC ACCELERATION SENSOR

TECHNICAL FIELD

The present invention relates to a vibration piezoelectric acceleration sensor (hereinafter, called VAS) to be used for a posture controller, and a vehicle and other mobile equipment control system.

BACKGROUND ART

Fig. 7 is a cross sectional view of a conventional acceleration sensor. As shown in Fig. 7, diaphragm 2 is formed in a rear side of chip 1, and a plurality of distortion sensing resistors 3 are disposed on a surface side of the chip, an opposing side of the diaphragm formed. At an other part of the surface side of chip 1, a semiconductor integrated circuit for computing acceleration, and thin film resistor 4 for adjusting performance of the semiconductor integrated circuit are disposed. Protection film 5 is formed on the surface side covering at least thin film resistor 4 but not covering distortion sensing resistors 3. On the rear side of chip 1, glass weight 6 is attached.

When acceleration is applied to thus constituted conventional acceleration sensor, a stress is applied to weight 6, then the sensor detects the acceleration with a deformation of distortion sensing resistor 3. When two axes detection is required, two identical sensors are disposed crossing with each other at right angles. An example of this type of conventional acceleration sensor is disclosed in Japanese Patent Unexamined Publication No. H5-288771 (document 1).

Another example of this type of conventional sensor is disclosed in Japanese Patent Unexamined Publication No. H5-80075 (document 2). Fig.8 is a block

diagram showing a constitution of the acceleration sensor. As shown in Fig. 8, the sensor is composed of piezoelectric element 11 outputting a signal corresponding to acceleration G, impedance converter 12 converting the signal output from piezoelectric element 11, filter 13 filtering an unneeded signal from the signal output from impedance converter 12, amplifier 14 amplifying a needed signal output from filter 13, alternating signal output device 16 outputting an alternating signal synchronized with a synchronism of a timing signal input from an outside, and capacitor 17 connected in series between alternating signal output device 16 and piezoelectric element 11.

A voltage signal output from thus constituted conventional acceleration sensor is input to measuring/operating unit 18 and controller 15. When two axes detection is required, two identical sensors are disposed crossing with each other at right angles for detection.

In the acceleration sensor in document 1, several percent of change in resistance value can be identified with a semiconductor resistor distortion formula. However, a problem exists that accurate acceleration detection is difficult because a variance in the change of the resistance value is wide and a signal is affected by a change in temperature of processing circuits.

With a constitution in document 2 where the piezoelectric element is used for detecting displacement speed of the element, detecting of such as a component of static gravitational acceleration is difficult because of its detecting mechanism. Two sensors are required for two axes detection. Thus, problems of cost increase and possible variation in performance exist.

SUMMARY OF THE INVENTION

This invention includes an element comprising a frame, a pair of diaphragms linearly and oppositely disposed on the frame, an under part electrode which is successively stacked on the diaphragm, a piezoelectric thin

film, an upper part electrode, a support body supporting the diaphragms at an adjacent one end of each diaphragm, and a holding part holding the support body slidably in a linear direction, in which the diaphragms are extended and retracted by an acceleration transmitted to the support body through the holding part of the element, and in which the acceleration is detected through a change in a natural oscillation frequency of the diaphragm. A pair of diaphragms are linearly and oppositely disposed crossing the pair of diaphragms that is linearly and oppositely disposed on the frame, detecting the acceleration in two axes directions. With this arrangement, both static and dynamic acceleration can be detected along two axes directions without being affected by noise or other environmental change. Thus, a highly reliable vibration piezoelectric acceleration sensor which operates under severe temperature changing environment is provided.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view showing a structure of an element of a vibration piezoelectric acceleration sensor (VAS) in accordance with a first embodiment of the present invention.

Fig. 2 is a perspective view showing a structure of a diaphragm of the VAS in accordance with the first embodiment of the present invention.

Fig. 3A is a drawing showing a constitution of a VAS in accordance with the first embodiment of the present invention.

Fig. 3B is a drawing showing a constitution of a VAS in accordance with the first embodiment of the present invention.

Fig. 3C is a drawing showing a constitution of a VAS in accordance with the first embodiment of the present invention.

Fig. 3D is a drawing showing a constitution of a VAS in accordance with the first embodiment of the present invention.

Fig. 4 is a circuit diagram showing a constitution of 2 axes detection of the VAS in accordance with the first embodiment of the present invention.

Fig. 5A is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

Fig. 5A is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

Fig. 5B is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

Fig. 5C is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

Fig. 5D is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

Fig. 5E is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

Fig. 5F shows a production process of the VAS illustrating its production process in accordance with the first embodiment of the present invention.

Fig. 6 is a drawing showing a constitution of a control system of an airbag using a VAS in accordance with a second embodiment of the present invention.

Fig. 7 is a sectional view showing a constitution of a conventional acceleration sensor.

Fig. 8 is a block diagram showing a constitution of another conventional acceleration sensor.

REFERENCE MARKS IN THE DRAWINGS

20 Si layer

21 substrate

22 SiO_2 layer (etching stopper)

23 diaphragm

23a, 23b, 23c, 23d diaphragm

23e, 23f, 23g, 23h, 23i arm

24 under part electrode

25 piezoelectric thin film

26 upper part electrode

26a detecting electrode

26b driving electrode

27 resist

28 side ditch

29 hole

30 side hole

31 frame

32, 32a, 32b, 32c, 32d holding part

33 support body

34 basal part

35 element of VAS

36a signal detecting line

36b signal driving line

38 amplifying circuit

39 F/V converter

40 AGC circuit

41 VAS device

41a, 41b, 41c, 41d VAS

42,43 differential circuit

44 vehicle body

45, 46 airbag

47 airbag mouth opening device

48 driver

49 moving direction

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Following, preferred embodiments are explained in detail with reference to the drawings. The drawings are schematic diagrams and they do not necessarily show correct dimensional relationships between the constituents.

FIRST EXEMPLARY EMBODIMENT

As shown in Fig. 1 and 2, diaphragms 23a to 23d having a natural oscillation frequency are disposed in frame 31. Support body 33 changes the natural oscillation frequency of diaphragms 23a to 23d. Holding parts 32a to 32d are formed in a meandering manner for holding the support body in a slidable manner and in a linear direction. In this constitution, diaphragms 23a to 23d extend and retract freely, therewith acceleration can be detected in a highly responsive and a highly accurate manner without being affected by a change in temperature.

Diaphragm 23a is formed in a wedge shape and has basal part 34 at each end of the diaphragm, one basal part 34 being held by frame 31 and an other basal part 34 being held by support body 33. Support body 33 is held by frame 31 via holding part 32a formed in the meandering manner, thus moving back-and-forth in a linear direction. Here, only diaphragm 23a disposed on frame 31 is explained, but a same principle is applied to other diaphragms 23b to 23d, so detailed explanation on them are omitted.

Arm 23i is formed like being extended from basal part 34. By forming arm 23i, sharpness of resonance frequency is increased by at least 2 to 3 times, and the increased resonance sharpness enhancing an accuracy of detection. Because a higher change ratio of resonance frequency can be obtained with

acceleration, the acceleration can be detected highly accurately without being affected by a change in temperature.

Following, configuration of the diaphragm is explained in detail taking diaphragm 23a as an example in Fig. 2.

Diaphragm 23a as illustrated in Fig. 2 is composed of Si layer 20 formed on SiO_2 layer 22, under part electrode 24 formed on Si layer 20, piezoelectric thin film 25 formed on under part electrode 24, and an upper part electrode formed on piezoelectric thin film 25. The upper part electrode is composed of driving electrode 26b and detecting electrode 26a. Driving electrode 26b and detecting electrode 26a are formed along a center part of the wedge shape constituting diaphragm 23a, and the electrodes are extendedly formed onto support body 33 and frame 31. With this constitution, a center portion of holding part 32a vibrates least not generating electromotive force by displacement, so that modulation signal is hardly interposed on a resonance frequency of diaphragm 23a thereby only resonance frequency of diaphragm 23a can be detected.

Furthermore, driving electrode 26b and detecting electrode 26a has a tapping electrode (not illustrated) at a predetermined part of the electrode extended to frame 31, and the tapping electrode is drawn to a control circuit (not illustrated). Since the tapping electrode is disposed on non-vibrating frame 31 without influencing vibration of diaphragm 23a, acceleration can be detected highly accurately without being affected by a change in temperature.

Still furthermore, driving electrode 26b and detecting electrode 26a are disposed symmetrically with respect to a central axis that crosses a longitudinal direction of diaphragm 23a and equally divides diaphragm 23a. By dividing an effective area of diaphragm 23a equally, detecting sensitivity through driving of diaphragm 23a and detecting from diaphragm 23a is maximized.

Next, working principle of thus constituted vibration piezoelectric acceleration sensor (VAS) in accordance with the exemplary embodiment is explained. Drawings 3A to 3D show constitution of the VAS in accordance with the exemplary embodiment, and each drawing having corresponding diaphragm 23a to 23d. Element having diaphragm 23a as illustrated by Fig. 2 is shown by an equivalent circuit 35.

The VAS includes signal detecting line 36a, signal driving line 36b, amplifying circuit 38 for amplifying a weak signal and driving diaphragm 23a of element 35, F/V converter 39 for converting a frequency of input signal into a voltage, and AGC circuit 40 for controlling a voltage level of output signal from amplifying circuit 38. Element 35 is attached to a main body (not illustrated) like the main body holding element 35 with frame 31.

First, when an electric power is input to VAS 41a, a signal including a noise is input to amplifying circuit 38 for being amplified. The amplified signal is input through signal driving line 36b to driving electrode 26b of element 35, vibrating diaphragm 23a. Electrical charge is excited at piezoelectric thin film 25 in diaphragm 23a to detecting electrode 26a, which is input from detecting electrode 26a through signal detecting line 36a to amplifying circuit 38. This process in the closed loop is repeated until the signal is stabilized into a stationary state of resonance frequency of natural vibration. Then, the resonance frequency signal of natural vibration is input to F/V converter 39 and is converted to a predetermined voltage. AGC circuit 40 works when a voltage level that is output from amplifier 38 becomes too large to cause a distortion of the signal, namely AGC circuit acts achieving an accurate F/V conversion without an error.

When acceleration is applied from an external source, an inertia force is applied from frame 31 to support body 33 held by holding part 32a, moving the support body in back and force directions along a linear line. With this back

and forth movement, diaphragm 23a vibrating in a stationary state contracts and retracts changing the resonance frequency of natural vibration of diaphragm 23a. Thus, the change in the resonance frequency of the natural vibration is detected corresponding to the acceleration applied. With this constitution, a higher change ratio of the resonance frequency can be obtained, namely acceleration can be detected highly accurately without being affected by a change in temperature.

In above explanation, only diaphragm 23a is explained. Since other diaphragms 23b to 23d are corresponded to Fig. 3B to 3D and their working mechanism is similar to 23a, explanation of them is omitted.

Fig. 4 shows a constitution of a main body of VAS 41. It is a two axes detection system in which differential circuit 42 and 43 each obtaining a differential voltage as an output signal from VAS 41a to 41d, making them an acceleration detection signal of X-axis and Y-axis. Because differential circuits 42 and 43 differentially cancel out changes in performance of each element and circuit, further stabilization can be expected.

Following, production method of the VAS in accordance with the exemplary embodiment is explained. Figs. 5A to 5F are production process drawings showing a production method of the VAS in accordance with the exemplary embodiment, each illustrating cross sectional view of a center part of diaphragm 23a.

First, as illustrated in Fig. 5A, forming etching stopper 22 made of SiO_2 on substrate 21 made of Si for stopping etching, then forming Si layer 20 on etching stopper 22. Thickness of substrate 21 is 500μm, etching stopper 22 is 2μm, and Si layer 20 is 10μm.

Following, forming Ti in a thickness of 50Å on Si layer 20 by high frequency sputtering, and then forming platinum in a thickness of 2000Å, constituting under part electrode 24, as illustrated in Fig. 5B. Next, forming

piezoelectric film 25 made of PZT (Lead Zirconate Titanate) in a thickness of 25μm on the platinum, then forming Ti layer in a thickness of 100Å on piezoelectric film 25 by vapor deposition, using a metal mask for obtaining a desired pattern, and then similarly forming gold in a thickness of 3000Å on the Ti layer by vapor deposition, thus constituting upper part electrode 26 having a prescribed pattern. Next, forming resist 27 on the gold, a resist for serving as an etching mask. A reason for using PZT material is for obtaining a higher conversion of resonance frequency changed by acceleration.

Next, forming side ditch 28 shown in Fig. 5C. In addition to above explained diaphragm, support body 33 and holding part 32 can be made of Si, therewith resonance frequency correspondingly changing with a stress of diaphragm 23 caused by acceleration can be stably improved.

Next, as shown in Fig. 5D, forming resist 27 in a predetermined pattern at a rear side of substrate 21, and then etching the rear side of substrate 21, forming hole 29.

Next, as shown in Fig. 5E, etching the side of resist 27 again, forming side hole 30. Then, removing resist 27 at the rear side. Thus, diaphragm 23 in a thin size and in a wedge shape is manufactured, as shown in Fig. 5F.

Detection sensitivity can be further improved by adding mass to an upper or a lower surface of support body 33. Increased mass of support body 33 strengthen the stress applied to diaphragm 23a, increasing a degree of change in a resonance frequency caused by acceleration, thus raising the detecting sensitivity.

SECOND EXEMPLARY EMBODIMENT

Fig. 6 shows an airbag control system, an application example of VAS 41 of the invention. VAS 41 is installed in X-axis and Y-axis direction. The control system is explained with reference to vehicle body 44, front airbag 45,

side airbag 46, mouth opening device 47 and driver 48. Arrow mark 49 indicates a moving direction of the vehicle.

Thus installed VAS 41 of the present invention controls works in vehicle 44 by controlling acceleration. When an acceleration value exceeds a certain level, the sensor sends out an acceleration output signal to airbag mouth opening device 47 for opening the airbag. The mouth opening signal is then transmitted to airbags 45 and 46 opening the airbag, thus realizing a safe driving with the sensor.

If acceleration is generated by collision in a moving direction (X-axis direction), front airbag 45 is opened, and if acceleration is generated in a side direction (Y-axis direction), acceleration signal in right and left directions opens side airbags 46, thus fatal human accident is prevented. Since 2 axes acceleration detection is made for both the front airbag and the side airbag, a high level of safety control is ensured.

In VAS 41 in accordance with the exemplary embodiment, vibration piezoelectric sensor 41 senses acceleration applied to vehicle 44 somewhat differently depending on a position where the sensor is placed, therefore vibration piezoelectric acceleration sensor 41 is preferably disposed in a central part of the vehicle 44 for detecting an average acceleration. Accordingly, in this exemplary embodiment, VAS41 is placed in a central part of the vehicle. Positional relationship between a driver and an airbag in a vehicle is not limited to one arranged in this exemplary embodiment. Even if the driver is sitting at a left side of the vehicle with regard to the moving direction, an identical effect is provided.

INDUSTRIAL APPLICABILITY

The VAS according to the present invention detects a high change ratio of resonance frequency caused by acceleration, and the acceleration can be

detected highly accurately with two detections without being affected by a change in temperature. Accordingly, the sensor can be used for an airbag control system, as well as for a sensor detecting gravity on the earth as a static acceleration. The static acceleration detecting capability can be utilized for a sensor detecting an angle of inclination, and the angle of inclination detection capability can be utilized for a navigator navigating a three dimensional position including an altitude.